Ecological Network Planning for the Asiatic black bears in Fuji-Tanzawa region, Japan

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Abstract – The Japanese National Biodiversity Strategy 2010 calls for the creation of ecological networks as a biodiversity conservation policy. This study proposed a plan of ecological networks to conserve two threatened local populations of Asiatic black bear (*Ursus thibetanus japonicus*) in Fuji and Tanzawa region in Japan with the support of GIS technologies. Using the predicted habitat patches of bears, current protected areas, road, vegetation cover types, land use, and altitude, GIS-based modeling was applied. The planned ecological networks consisted of 1582 km^2 of core areas, 182 km^2 of ecological corridors, and 618 km^2 of buffer zones. If the plan will be implemented, 4 % of forest area will be expanded and total cost is 55 trillion yen. GIS-based modeling was proved to be effective for generating spatially explicit plan.

Keywords: Asiatic black bear, Ecological network planning, Fuji-Tanzawa region, GIS, Japan, *Ursus thibetanus japonicus*

1. INTRODUCTION

In Japan, the National Biodiversity Strategy 2010 was adopted in 2010. Hence, measures from the perspective of ecosystem conservation, especially of animal habitat conservation, should be institutionalized. As the most important theme in the national strategy, "conservation of important areas and creation of ecological networks" are highlighted. Doko et al. (2011) proposed a quantitative method for assessing how necessary it is for a species to be included in ecological networks, and found that the total Asiatic black bear (*Ursus thibetanus japonicus*) population of the Fuji-Tanzawa region in Japan is considered to be "endangered"; thus, an adequate population size might be difficult to maintain even if this region were to be internally connected by means of an ecological network.

Thus, this study aims to propose ecological networks in order to conserve sufficient population size of the Asiatic black bears in Fuji-Tanzawa region of Japan (34◦37' 34.51" to 36◦10'7.51" N and 137◦34' 30.08" to 139◦35' 36.08" E), which is located at the Central Japan where the large mammals inhabit. The total study area covers 5630 km^2, which contains three prefectures: Kanagawa Prefecture, Shizuoka Prefecture and Yamanashi Prefecture. Asiatic black bear population in this region is estimated to be 242, with 179 individuals in the Fuji local population, 26 in the Tanzawa local population, and 37 in the corridor patch between above-mentioned two local populations (Doko et al., 2011). This corridor patch is considered to be equivalent to Mishoutai local population (Doko et al., 2011). Because of the presence of new and upgraded roads, local black bear populations have seen their habitats fragmented by deforestation. The Tanzawa local population, in particular, has been deemed a "population which, due to its small size, should be protected" (Japanese Mammals Society, 1997).

2. METHODS

2.1 Design of ecological infrastructure

Based on the analysis on current Asiatic black bears' habitat (Doko et al., 2011; Doko et al., 2009) and observation through 4-years continuous field surveys of Asiatic black bears of Tanzawa local population, goals and action plans were established (Table 1). Mapping ecological networks requires identifying core areas, ecological corridors, and buffers (Jongman, 1995). The methods applied in this study were combination of several previous studies (Gurrutxaga et al., 2010; Nagahama et al., 2006; Quinby and Lee, 2002). Geographic Information System software (ArcMap 9.3 ®, ESRI Inc.) was used for analysis and modeling ecological infrastructures.

Core areas were established according to the identified Asiatic black bears' habitat and newly proposed protected area with enhanced zoning regulations. Core areas regarding the current bears' habitat comprise three local populations (LP): Fuji LP, Tanzawa LP, and Chichibu LP (Doko et al., 2011). From current protected area, targeted existing systems were wildlife protection area and natural parks, because nature conservation area does not provide any form of habitat protection at all (Doko et al., 2011). The buffer zones of 500 m from core areas were taken according to the standard ecological network design (Jongman, 1995). For subpopulations in Mt. Ashitaka and Mt. Furo, which were identified to be isolated and fragmented (Doko *et al.* 2011), buffer analysis (500 m from subpopulations) was taken. These buffered areas were merged by ArcMap and prepared as "buffer zones" which consist of ecological networks.

Once the core areas were identified, allocation of ecological corridors should be examined. Mishoutai local population is expected to function as an existing ecological corridor which connects Fuji and Tanzawa region (Doko et al., 2011). Additionally, following corridors were newly proposed: 1) corridors between subpopulation of Mt. Ashitaka and Fuji local population, 2) corridors between subpopulation of Mt. Furo, and (a) Fuji local population, (b) Tanzawa local population, and (c) Mishoutai local population, and 3) corridors between Fuji local population and Chichibu local population. The GIS method of least-cost modeling was applied to estimate the connectivity of the landscape matrix (Adriaensen et al., 2003). In the ArcMap software, least-cost modeling is implemented as Least Cost Path Analysis (LCPA) under the Spatial Analyst tool. The least cost corridor function, which can produce the corridor raster, was used in this study, as the purpose is to identify the optimal swath of corridors. Cost layer and source layer were required. Cost layer represents the map of the resistance of landscape matrix to the mobility of the selected species (Gurrutxaga *et al.* 2010). In order to avoid subjectivity, the values of relative importance by

Table 1 Planned goals and action plans for scenario II to build ecological networks

Item	Goals and action plans
Habitat condition of Asiatic black bears	
Geographic location	• To allocate Fuji local population, Tanzawa local population, and Chichibu local population as core areas in the ecological network design. • To design buffer zones from core areas. • To make ecological corridors between subpopulation of Mt. Ashitaka and Fuji local population. • To make ecological corridors between subpopulation of Mt. Furo, and (a) Fuji local population, (b) Tanzawa local population, and (c) Mishoutai local population. • To make ecological corridors between Fuji local population and Chichibu local population. • To make buffer zones which surround subpopulations of Mt. Furo and Mt. Ashitaka. • To use the Mishoutai local population as an existing corridor which connects Fuji and Tanzawa local populations.
Population size	• To maintain at least 400 individuals for sustainable local populations among Fuji, Tanzawawa, and Chichibu-Tama regions in order to avoid future extinction.
Influential environmental factors to Asiatic black bears' habitat selection or preference	
Vegetation	• To protect and increase broad-leaved deciduous forest in the montane zone, which was the most frequent place (65 %) where the Asiatic black bear was found.
Roads	• To build wildlife passages over the highways (CHUO EXPRESSWAY, etc) as a mean of mitigating the effects of physical barrier of movement from Fuji-Tanzawa local populations to Chichibu local population. • To make mitigation for the general roads wider than 1.5 m, when there is no control of use of cars, e.g. to build ecological bridge over these roads. • To maintain restriction of vehicles in the Tanzawa Quasi-National Park, because it is an effective measure for preserving the Asiatic black bear population.
Rivers	• To keep the status quo at least for the small rivers (*sawa*) in the Tanzawa Mountains are narrow (3.5 m) and shallow (13.4 cm), with relatively little volume of flow (typically 0.14 m^3/second), as the Asiatic black bear uses the shallows of rivers as places to drink, and crosses them with little cost of movement.
Relation of human's land use and Asiatic black bears' habitat	
Conservation gaps between protection area and bear's habitat	• To include the full area of subpopulation of Mt. Ashitaka in future zoning plans. - to designate this area as wildlife protection areas. - to cover this area fully by the Special Zones of the Fuji National Park. • To include the isolated subpopulation of Mt. Furo in future zoning plans. - to designate this area as prefectural natural parks. • To include the Mishoutai local population in the wildlife protection areas and prefectural natural parks. • To protect the corridor part between Fuji local population and Chichibu-Tama local population by the Special Zone of the Fuji National Park.
Ownership of land	• To shift attention to regulations and laws concerning endangered species occurring on private land (699km^2), where is home of 154 bears, e.g. to purchase private lands by government, or to implement "management commissions", which allows landowners of private and communal forests to outsource management of their forests to the government in return for tax breaks. - to change the category of forest, which belongs to private land and where bears inhabit, to national forest.

a jackknife test were referred to determine resistance values. Resistance values of land use, altitude, vegetation cover types, and distance to roads were combined by assigning proportion of 10%, 23%, 24%, and 43% respectively.

2.2 Two scenarios on land use

Two types of land-use planning scenarios focusing on different level of nature conservation were generated: 1) implementing current land-use plans which would not add new conservation policy (scenario I) and 2) implementing ecological networks which were integrated into the current land-use plans (scenario II). The spatial data regarding actual land use was derived from "Digital national land information (Download service)" provided by the Counselor National and Regional Planning Bureau (http://nlftp.mlit.go.jp/ksj/). This represents the scenario I, and as for scenario II, proposed ecological networks were integrated as new forest area into the future land use.

Area of corresponding land use categories and proportion of these categories were calculated, so that this enables to compare with current actual land use. Additionally, for effective and efficient ecological network planning, expenses for this projected future land use plan were estimated. Expenses necessary for this plan were calculated based on unit price (Table 2). Unit price was determined by referring to the one proposed in similar researches in Japan to compare several alternative scenarios for development of ecological networks (Nagahama et al., 2006), and through consultation with experts working in a consultancy company in a field of environmental impact assessment and wildlife restoration.

3. RESULTS

3.1 Ecological network planning

The planned ecological network in Fuji-Tanzawa region in Japan is shown (Figure 1). In total, the planned ecological networks comprised 1582 km^2 of core area, 182 km^2 of ecological corridors, and 618 km^2 of buffer zones. These corresponded to 28 %, 3 %, and 11 % of total study area for core area, ecological corridors, and buffer zones, respectively.
The zoning regulations of wildlife protection areas and natural parks (prefectural natural parks and national parks) were

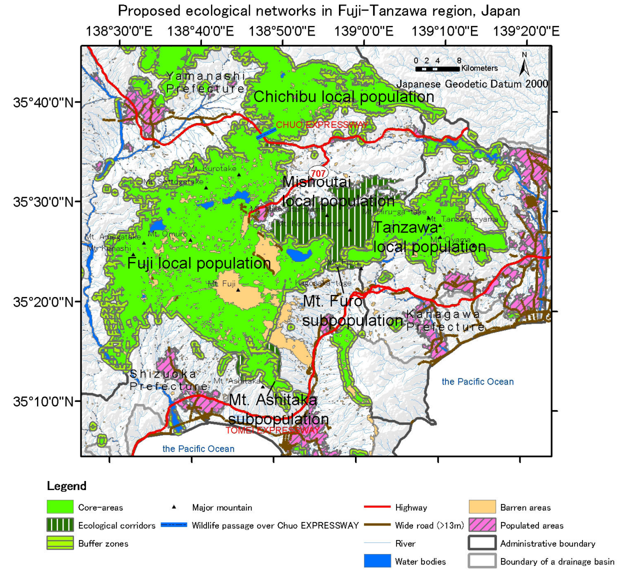

Figure 1 Ecological network plan for conserving two local black bear populations in Fuji-Tanzawa region, Japan

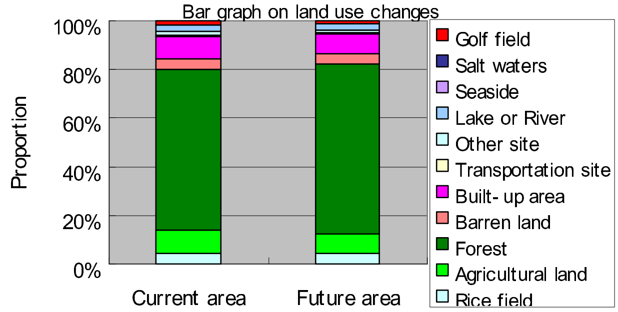

Figure 2 Comparison of proportion regarding land use categories between current and proposed land use

Note. "Agricultural land" here means all agricultural fields except rice field, and it includes crop fields and orchard fields.

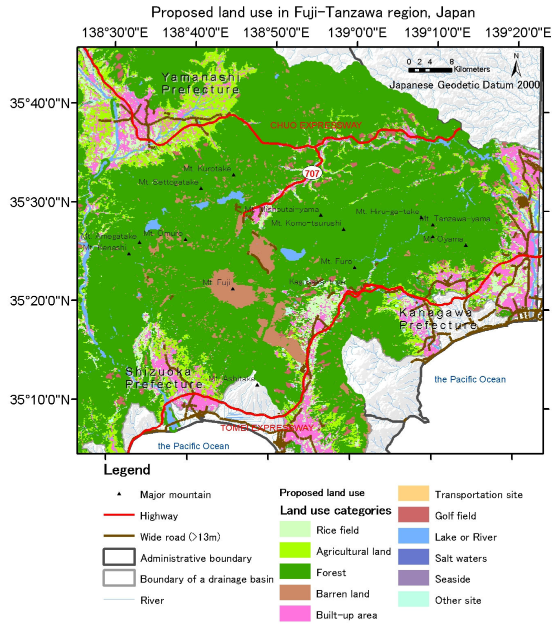

Figure 3 Predictive maps of land-use based on proposed ecological networks in Fuji-Tanzawa region, Japan

examined. It was found that the subpopulation of Mt. Furo was already fully covered by prefectural natural parks. When Mishoutai local population and subpopulation of Mt. Ashitaka were designed to be covered, the total of 150 km^2 of protected areas (132km^2 of prefectural natural parks, and 18 km^2 of Special Zones of Fuji National Park) was newly proposed. Moreover, in this study, the private forest, where the Asiatic black bears' potential habitat was estimated, was planned to be registered as national forest. This newly classified private forest comprised 1561 km^2 in total, and thus the total national forest in this area became 1872 km^2. As a mitigation measure for Chuo Expressway, locality of a wildlife passage was proposed and mapped (Figure 1).

3.2 Predicted land use and expenses

The current land use comprise 11 categories, namely, rice field, agricultural land, forest, barren land, built-up area, transportation site, golf field, lake or river, salt waters, seaside, and other area. Proportion of areas which comprised land use categories was calculated (Figure 2). In current land use, 66 % of study area was covered by forest; meanwhile built-up area comprises only 9 %. On the other hand, 14 % of total area was related to the agricultural fields, including crops, orchard, and rice. As the area such as seaside and salt waters were extremely small, so the proportion was considered to be 0 %.

Based on the proposed ecological networks, a predictive land use map is shown (Figure 3). Changes between current land use and proposed one were compared (Figure 2). The proposed land use map comprised 70 % of forest, which was increased by 4 % compared to the current land use. On the other hand, rice field and agricultural field decreased by 2 % in total. Built-up area decreased from 9 % to 8 %, a decrease by 1 % compared to the current land use. 3 % of transportation site decreased from current land use to proposed one. Other categories did not show much difference between two land use maps. Expenses for implementing the action plans were estimated to cost

Table 2 Total estimation for implementation of ecological networks in Fuji-Tanzawa region, Japan

Item of action plan	Expenses for a unit	Total (1,000,000 yen)
Maintenance and change of current protected area *[1]	0 yen	0
Establishment of corridors (allocation of forest patches) *[2]	350,000 yen/one mature tree	9,555,000
Protection of isolated habitat patch *[2]	350,000 yen/one mature tree	7,875,000
Establishment of buffer zones *[2]	350,000 yen/one mature tree	32,445,000
Maintenance of roads (building ecological bridges)	21,750,000 yen/one location	22
Utilization of private forests *[3]	342,000 yen/100 m2	5,338,620
Total		55,213,641

*[1] It was assumed that the expenses for maintenance and change of current protected area are free when the government is in charge. *[2] The density of transplanting tree was estimated to be 1,500 mature tree/ha, which is the standard level in Japan. *[3] The expenses for land acquisition were not included.

55,213,641 Japanese yen in total (Table 2).

4. DISCUSSION

Proposed ecological networks

The planned ecological networks in Fuji-Tanzawa region consisted of 1582 km^2 of core areas, 182 km^2 of ecological corridors, and 618 km^2 of buffer zones (Figure 1). However, when this plan is integrated into a current land use, the substantial changes are expected to be little; in fact the forest expansion is projected from 66 % to 70 % by 4 % increase only. According to this plan, 2 % of agricultural or rice field, 2 % of built-up area, and 3 % of transportation site should be converted to forest newly. The total forest area proposed in this study is estimated to be 3962 km^2. Our cost analysis revealed that implementation of this plan requires 55 trillion yen. Compared to the estimated expenses of 345 billion yen/30 years for implementing an ecological network based on the wildlife restoration scenario for Japanese squirrel (*Sciurus lis*) (Nagahama et al., 2006), this figure of our plan is quite expensive. We attribute this difference to the size of study area and required size of habitat patches for target animals. While this study targets the Fuji-Tanzawa region which comprises 5630 km^2 of area, the study for Japanese squirrel targets the watershed of Arakawa River, which comprises 2940 km^2 in Saitama and Tokyo in Kanto region, Japan. The restoration plan for small mammals is considered to be relatively inexpensive compared to large mammals, such as bears. Attention is focused on biodiversity conservation as the Conservation on Biological Diversity (COP10) was held in Nagoya, 2010. To present the concrete ecological network plan as a case study in a certain place for a target species in this study is expected to contribute to the Japanese National Biodiversity Strategy 2010 which calls for the creation of ecological networks as a biodiversity conservation policy.

GIS-based methodology

The main contribution of this study is identification of core areas, ecological corridors, and buffer zones in a spatially explicit way using GIS-based mapping techniques and least-cost modeling. The cost-surfaces layer was calculated based on the mobility of Asiatic black bears. The methods applied in this study were combination of several previous studies (Gurrutxaga et al., 2010; Nagahama et al., 2006; Quinby and Lee, 2002). In many studies, the least-cost modeling approaches were applied to identify optimal corridor (for instance, see Gurrutxaga et al., 2010; Quinby and Lee, 2002). This methodology is objective and repeatable in agreement with Gurrutxaga et al. (2010). Especially in Japan, the government provides a variety of GIS products to public. The dataset used in this study can be acquired by other researchers easily. In this study, another approach to project future policy scenarios into landscape ecological network design was integrated into the least-cost modeling. By this integration, the land use can be compared between current use and future use, so that for policy makers, this spatial information, which delineated the geographic location of necessary ecological infrastructure, would be expected to be useful. When running least-cost modeling, the residence values are needed to be considered carefully, as this procedure determines the outcome-corridor. In our study, as we could use the prior knowledge on Asiatic black bears' movement barriers and preference of resource selection, it is considered that we could reduce the subjectivity as much as possible. However, the sensitivity of Asiatic black bears to the land use categories was required to be assumed, due to lack of previous information. For future studies, it is recommended to study the sensitivity of a targeted species to a specific environment or land use will be examined carefully prior to running this model.

5. CONCLUSIONS

This study proposed ecological networks to conserve two threatened local populations of Asiatic black bear in Fuji and Tanzawa region in Japan with the support of GIS technologies and by 4-years continuous field surveys of Asiatic black bears of Tanzawa local population. The planned ecological networks consist of 1582 km^2 of core areas, 182 km^2 of ecological corridors, and 618 km^2 of buffer zones. If the plan is implemented, 4 % of forest area is expanded and total estimate is 55 trillion yen. GIS-based modeling was proved to be effective for generating spatially explicit plan, and to be objective and repeatable, and thus the methods proposed here is applicable for other ecological network plans. The ecological network plan proposed in this study is expected to contribute to the Japanese National Biodiversity Strategy 2010 which calls for the creation of ecological networks as a biodiversity conservation policy.

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